National Aeronautics and Space Administration

NASA Advisory Council Aeronautics Committee Report

Ms. Marion Blakey
Chair
NASA Headquarters

July 28th, 2016

Aeronautics Committee Membership

- Ms. Marion Blakey, Chair, *Rolls Royce North America*
- Mr. John Borghese, Vice Chair, *Rockwell Collins*
- Dr. Missy Cummings, *Duke University*
- Dr. John Paul Clarke, *Georgia Institute of Technology*
- Dr. Michael Francis, *United Technologies*
- *Dr. Greg Hyslop, The Boeing Company **
- Dr. Lui Sha, *University of Illinois*
- Dr. Karen Thole, *Pennsylvania State University*
- Dr. David Vos, *Google [X]*

** New Member*

Areas of Interest Explored at Current Meeting

Topics covered at the Aeronautics Committee Meeting held on July26th, 2016 in Cleveland – GRC/OAI:

- NRC-led Low Carbon Study (Thrust 4)
- Thrust 4 Roadmaps Outbrief *
- New Aviation Horizons Formulation Rationale and Approach *

* These topics have related findings provided by the Aeronautics Committee

NASA Aeronautics

NASA Aeronautics Vision for Aviation in the 21st Century

6 Strategic Research and Technology Thrusts

T1 — **Safe, Efficient Growth in Global Operations**
- Enable full NextGen and develop technologies to substantially
- reduce aircraft safety risks

T2 — **Innovation in Commercial Supersonic Aircraft**
- Achieve a low-boom standard

T3A ST
T3B VL — **Ultra-Efficient Commercial Vehicles**
- Pioneer technologies for big leaps in efficiency and environmental performance

T4 — **Transition to Low-Carbon Propulsion**
- Characterize drop-in alternative fuels and pioneer
- low-carbon propulsion technology

T5 — **Real-Time System-Wide Safety Assurance**
- Develop an integrated prototype of a real-time safety monitoring and assurance system

T6 — **Assured Autonomy for Aviation Transformation**
- Develop high impact aviation autonomy applications

NRC Committee to Reduce Carbon Emissions from Commercial Aviation

- **KAREN A. THOLE**, *Co-Chair,* Pennsylvania State University
- **WOODROW WHITLOW, JR.**, *Co-Chair,* Cleveland State University
- **MEYER J. BENZAKEIN**, The Ohio State University
- **R. STEPHEN BERRY**, University of Chicago
- **MARTY K. BRADLEY**, Boeing Commercial Airplanes
- **STEVEN J. CSONKA**, Commercial Aviation Alternative Fuels Initiative
- **DAVID J. H. EAMES**, Rolls-Royce North America (retired)
- **DANIEL K. ELWELL**, Elwell and Associates, LLC
- **ALAN H. EPSTEIN**, Pratt and Whitney
- **ZIA HAQ**, U.S. Department of Energy
- **KAREN MARAIS**, Purdue University
- **JAMES F. MILLER**, Argonne National Laboratory
- **JOHN G. NAIRUS**, Air Force Research Laboratory
- **STEPHEN M. RUFFIN**, Georgia Institute of Technology
- **HRATCH G. SEMERJIAN**, National Institute of Standards and Technology
- **SUBHASH C. SINGHAL**, Pacific Northwest National Laboratory

Committee Tasking

- Develop a national research agenda to reduce life-cycle carbon emissions from global commercial aviation
- Focus primarily on propulsion and energy systems for large, commercial aircraft
- Consider technologies that could be introduced into service in the next 10 to 30 years
- Consider economic, technical, regulatory, and policy barriers
- Exclude non-technology, policy approaches (e.g., carbon taxes)

High-Priority Approaches

Implement a national research agenda that places the highest priority on the following approaches:

- Advances in aircraft and propulsion integration
- Improvements in gas turbine engines
- Development of turboelectric propulsion systems
- Advances in sustainable alternative jet fuels (SAJF)

NRC Committee Recommendation Organizational Research Priorities

- Government, industry, and academia are needed to implement the recommended research agenda.
- The relative priority that various agencies and organizations assign to the four recommended high-priority approaches and the research projects within each approach should be guided by:
  1) Importance that any given organization places upon the rationales associated with each approach;
  2) Resident expertise and mission objectives of the organization; and
  3) Desired nature of a given organization's research portfolio in terms of risk, technical maturity, and economic potential.

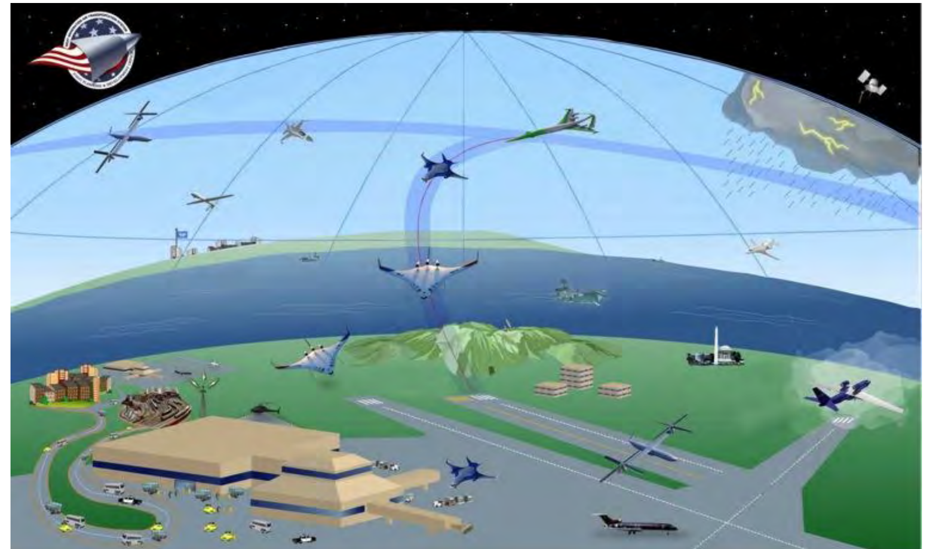
NRC Committee Concluding Remarks

- Four approaches were identified that have the potential to reduce carbon emissions resulting from commercial aviation—aircraft and propulsion integration, gas turbine engines, turboelectric propulsion, and sustainable alternative jet fuels (SAJF).
- Aircraft–propulsion integration and gas turbine engines are both well-established approaches that need to be pursued.
- Path forward is less certain for . . .
  - Turboelectric propulsion - Not clear when ready for practical application to commercial aircraft
  - SAJF: Need to overcome issues related to comparative cost of petroleum-based jet fuels

Report available at www.nap.edu/download/23490

A Vision for the Future of Civil Aviation

- There will be a radical increase in new and cost-effective uses of aviation
- The skies will accommodate thousands of times the number of vehicles flying today
- Travelers will have the flexibility to fly when and where they want in a fraction of the time that it takes today
- All forms of air travel will be as safe as commercial air transport is today
- Subsonic transports will remain the backbone of long-haul global and domestic travel
- Significantly reduced carbon and noise footprints from aviation



- Low-carbon propulsion will be designed into vehicles of all sizes and missions
- Low-carbon propulsion will have its largest impact on aviation's carbon footprint via subsonic transports
- Low-carbon propulsion will enable new vehicles that create economic benefit for unique missions/services
- Alternative jet fuels will be the norm

Thrust 4 Roadmap Development

Two focused teams will result in one roadmap

Introduction & Overview

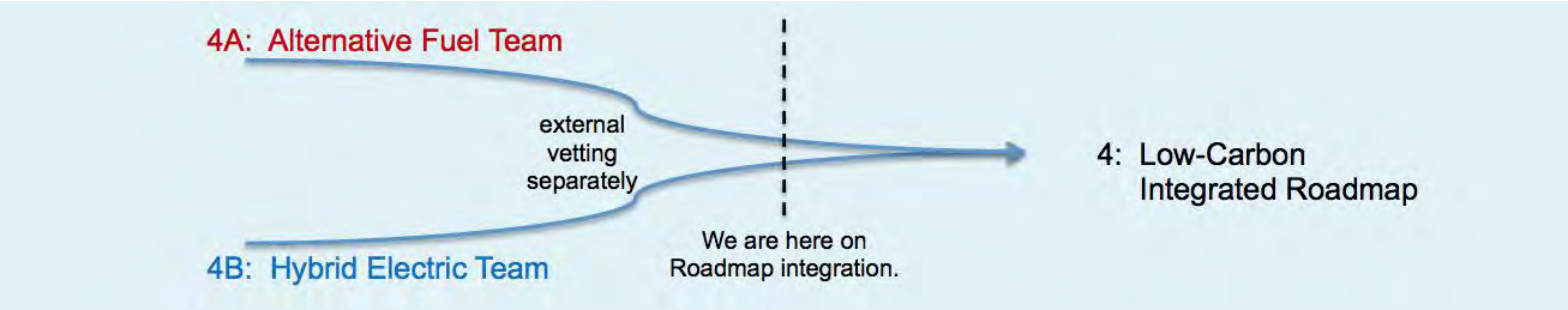
Thrust 4A—Low Carbon Emissions achieved through use of alternative jet fuels with lower life-cycle carbon footprints

- enable use in air vehicles with advanced, highly efficient propulsion systems
- inform/support the regulatory communities on the impact of the use of these fuels

- **Vision**: To reduce the carbon footprint of air transportation through effective use of lower life-cycle carbon alternative jet fuels with known impact on the environment.

Thrust 4B—Low Carbon Emissions achieved through use of alternative propulsion systems such as electric/hybrid electric propulsion

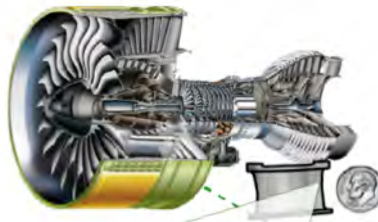
- **Vision**: To explore, advance and transform aviation via electric/hybrid electric propulsion integrated with airframes to increase aircraft functionality, reducing carbon emissions while improving operational efficiency and reducing noise



Thrust 4 Roadmaps

Alternative Jet Fuels

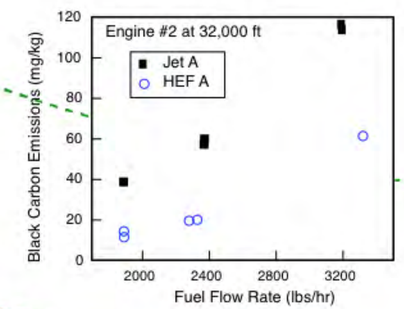
Optimize and accelerate the effective use



Explore and demonstrate combustor concepts that exploit future alternative fuels

Fully integrate with advanced engines

Certify, Operate



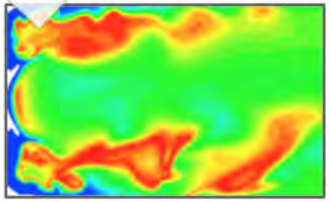
2040

2030

Characterize the performance and emissions of an increasing spectrum of alternative jet fuels in advanced combustors

Science to guide policy

2020



2015

Modeling & Simulation

Experimental Validation Data

Combustor/Fuel System Improvements

Explore Architecture

Advance scientific understanding relating fuels to combustion to emissions to atmospheric impact

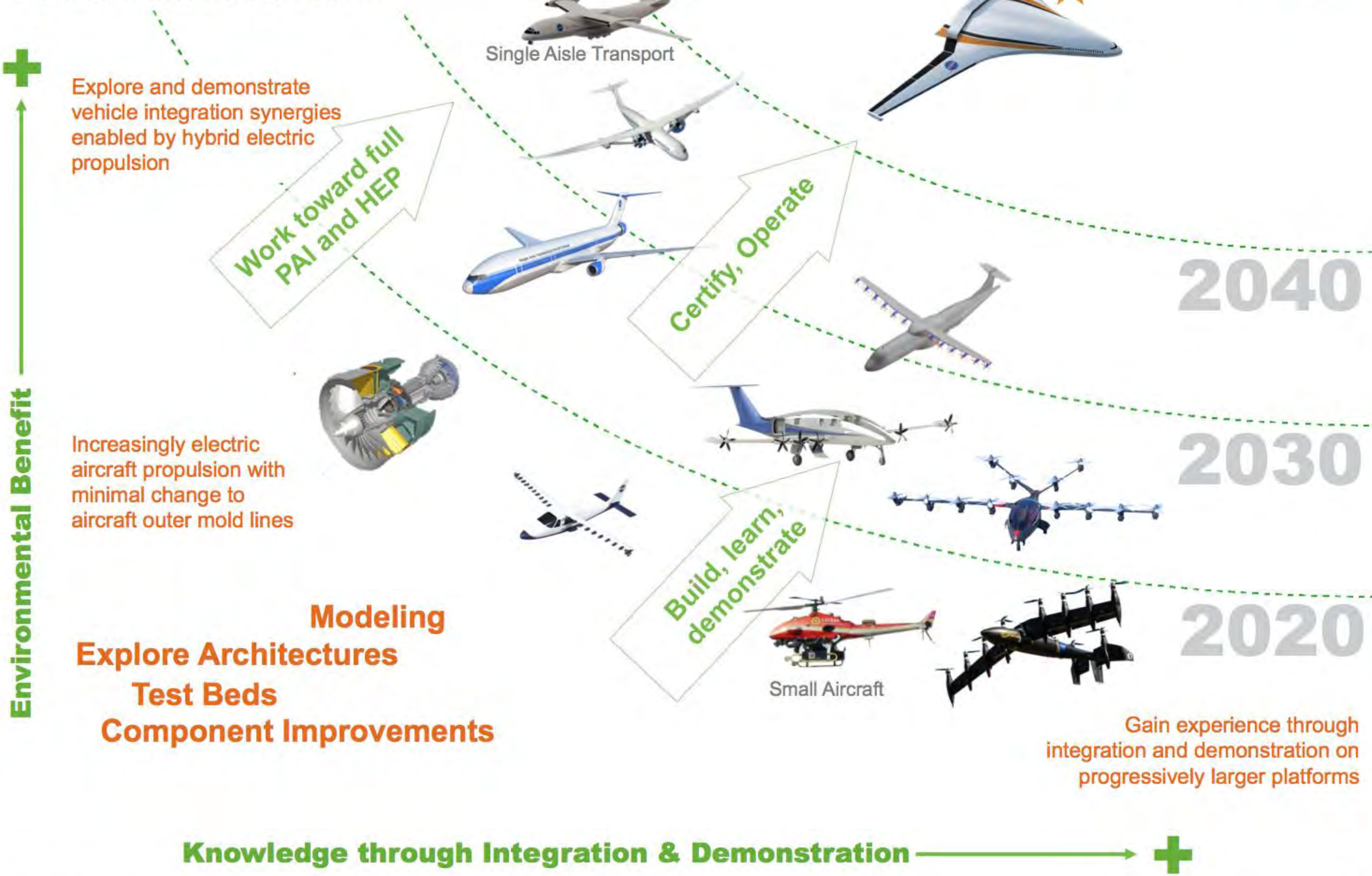
Optimized Design & Engineering for use of LCC Fuels

Knowledge through Basic Sciences

Thrust 4 Roadmaps

Hybrid Electric Propulsion

Prove Out Transformational Potential



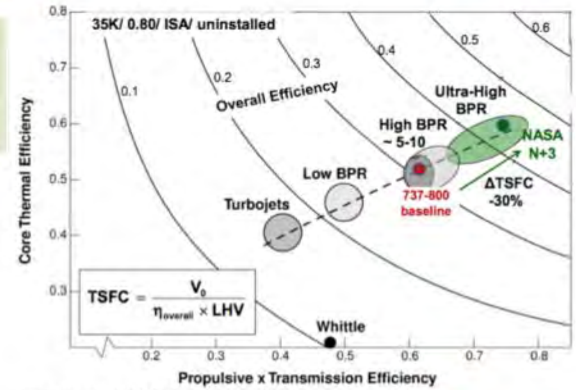
Thrust Relationships

What Distinguishes Thrust 4 from Thrust 3 (and 2) Propulsion?

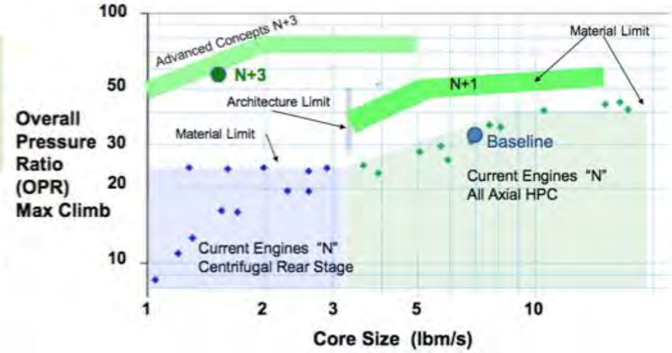
Ultra-Efficient Commercial Vehicles

Efficiency (use less energy)
Emissions (use less energy)
Noise (less perceived noise)

Airframe
Propulsion – Advanced Gas Turbines and Propulsors
Vehicle System Integration



Lord, et. al., AIAA SciTech15, AIAA-2015-0071



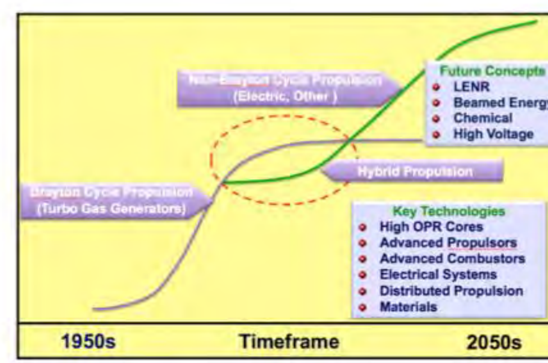
adv gas turbine
Small Core
fuel flexibility
hybrid systems

Transition to Low-Carbon Propulsion

Aviation Alternative Fuels (Drop-In)
- Reduce specific carbon (use cleaner energy)
- Clean, compact combustion
- Gas turbines needed for foreseeable future



Alternative Energy/Power Architectures
- Energy sector convergent technology*
- Promise of cleaner energy
- Potential for vehicle system efficiency gains (use less energy)
- Leverage advances in other transportation sectors
- Address aviation-unique challenges (e.g. weight, altitude)
- Recognize potential for early learning and impact on small aircraft



*energy sector includes other government agencies, industry, and academia

Committee Finding for ARMD AA on Thrust 4 Roadmaps

The Committee endorsed and complimented ARMD on the way that the strategy has been implemented and agreed that there is a clear beacon that's driving where NASA is going. The Committee encourages NASA to widen the trade space and not be afraid to try something new to reduce carbon emissions specifically not to be constrained by conventional boundaries. The Committee finds that in order to get there NASA has to try to incentivize and promote cross pollination of ideas to the main objectives of the strategy.

Integrated Aviation Systems Program

Mission Program

Integrated Aviation Systems Program

Conducts flight research on promising concepts and technologies at an integrated system level

Explores, assesses, and demonstrates the benefits of promising technologies in a relevant environment

Conducts research into unmanned system integration into the national airspace

Supports flight research needs across the ARMD strategic thrusts, programs and projects

Coordinates large-scale and small-scale flight demonstrations in support of Strategic Thrust areas

Maintains flight test assets and capabilities in support of ARMD flight demonstrations

Introduces risk-reduction activities

New Aviation Horizons initiative

- Flight demonstration planning to support needs across ARMD
- Develop/deliver flight validated technologies to US industry
- Enable US industry to engineer solutions to global challenges
- Inspire, develop, and educate next generation workforce to engineer future aviation systems
- Led by IASP AD for Flight Strategy

Projects

- UAS Integration in the NAS
- Flight Demonstrations and Capabilities
- Quiet Supersonic Technology Demonstrator
- UEST Demonstrations

New Aviation Horizons (NAH) Initiative

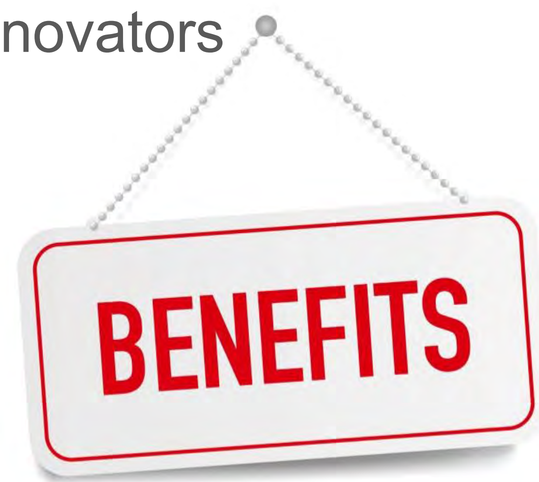
The centerpiece of NASA’s 10-year acceleration for advanced technologies testing is an ambitious plan to build five large-scale experimental aircraft- X-planes– that will flight test:

- New technologies
- Systems and
- Advanced aircraft and engine configurations

X-plane and demonstrators provide the “third-leg” of aero research making it possible to further increase the confidence and lower the risk associated with new technology/configuration development

NAH Will Offer Significant Benefits

- Demonstrate revolutionary advancements in aircraft and engine configurations that break the mold of traditional tube and wing designs
- Support the accelerated delivery to the US aviation community of advanced design and analysis tools
- Provide research results that inform domestic and international rulemaking, standards and regulations
- Enable US industry to put into service flight-proven transformative technologies that solve tomorrow's aviation challenges
- Inspire a new generation of aeronautical innovators



NAH Flight Demonstrator Plan

ARMD has developed a suite of Flight Demonstration development plans that will deliver:

- X-planes that integrate advanced concepts and technologies
- Advanced technologies proven through ground and flight tests
- Understanding of complex transformational flight systems including structures, aerodynamics, propulsion, controls and flight dynamics interactions
- Transformative research aligned with NASA Aeronautics Strategic Implementation Plan
- New approaches to NASA-Industry-Academia partnerships

NAH – Where Are We Today?

- Lockheed Martin Aeronautics Company has been awarded a preliminary design contract for a Low Boom Flight Demonstrator
- NASA has posted a Request for Proposals to guide the develop of ultra-efficient subsonic transport demonstrator through requirements definitions
  - Comprehensive description and technology maturation plan
  - Proposals due August 18th
  - Expect to award 5-6 contracts, 6 month duration
- NASA Aeronautics is ready to adapt plans to various funding levels and authorization language.

New Aviation Horizons Initiative

New Aviation Horizons Initiative answers the charge from AIA and AIAA “….support robust, long-term civil aeronautics research and technology initiatives….ensure US leadership in Aeronautics….to sustain a strong economy, maintain a skilled workforce, support national security and drive a world-class educational system.

Committee Finding for ARMD AA on the New Aviation Horizons Initiative

The Committee believes that the NASA plan for the X-planes program is an opportunity to highlight the technology development that is driving the future. The Committee agrees that this initiative has concrete and real benefits and will capture the minds of the next generation and will bring excitement to the public. The Committee suggests to open up the aperture to allow for the next breakthrough in sub-scale demonstrators and to not narrow our view with fixed solutions that have too many constraints. The Committee views this as an incredible opportunity to step up in order to maintain U.S. world leadership in the aerospace industry and to take advantage of the increase growth potential of the industry. The Committee commends NASA's efforts in bringing industry, academia and other government agencies to the table and being involved in the discussion.

2016 Work Plan

NAC Aero Committee Work Plan

1. Review the ARMD ten year investment strategy and discuss changes based on the FY17 President's budget. (March)
2. Review the overall Thrust roadmaps and provide feedback. (March, November)
3. Review the NASA – USAF collaboration efforts through the context of the Executive Research Committee (ERC). (March)
4. Review the Hypersonic research strategy at the $25M a year funding level and provide feedback on the technical content and partnering approach. (March)
5. Provide feedback on the NRC Low Carbon (Thrust 4) study and provide recommendations on how this report should influence the ARMD portfolio. (July)
6. Review the New Aviation Horizons formulation plan including the Low Boom Flight Demonstrator planning. Focus is on having a conversation about context and principles related to the planning for the flight demonstrators. The Committee will provide experiences, thoughts and recommendations about flight demonstrators. (July)
7. Review the ARMD integrated strategy for UAS (including UTM) research. (November)
8. Review the formulation and execution activities of both the Advanced Composites and the System-wide Safety Assurance projects. (November)
9. Review ARMD autonomy research strategy. (November)
10. Review CFD Vision 2030 implementation plan and synergy with the new funding model for key facilities to maintain aeroscience technical capability. (November)

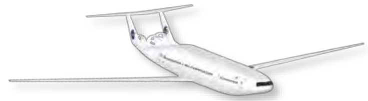
BACKUP

NASA Aeronautics Ready for Flight

Accomplishments and Planning

Scalable Convergent Electric Propulsion Technology and Operations Research (Sceptor)

D8-Double Bubble



Transonic Truss-Braced Wing (TTBW)

Hybrid Electric Propulsion (HEP)

1 Commission Studies

2 Individual Technologies

3 Subscale Models

4 Preliminary Design

5 Design & Build

6 Flight Test

Low Boom Flight Demonstrator (LBFD)

Box Wing Subsonic Transport

Hybrid Wing Body (HWB) Concept 2

Hybrid Wing Body (HWB) Concept 1

Ultra Efficient Subsonic Transport Demonstrators

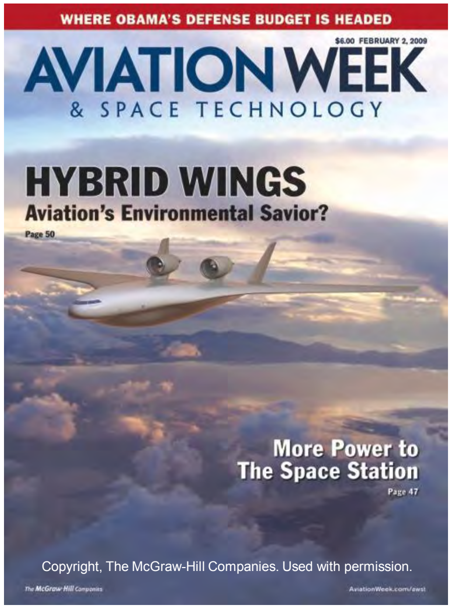
Benefits and Readiness

Transformational Benefits of Advanced Configurations and Technologies

Reduced Carbon Footprint/Fuel Burn (40-60% potential)

Reduced Noise (up to -42dB cum below Stage 4)

U.S. Technology Leadership—Advanced Structures, Aerodynamics, Propulsion, Controls, Integration



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HWB Concept 1 (Tailless)

- Hybrid/blended wing body without a tail
  - Non-circular, flat-walled pressurized composite fuselage
- Upper aft fuselage mounted propulsion
- Propulsion noise shielding
- Unique cargo door for military/civil application

HWB Concept 2 (Tail w/OWN)

- Hybrid/blended wing body with conventional T-tail
  - Non-circular, oval pressurized composite fuselage
- Aft, Over-the-Wing Nacelles
- Fan noise shielding from wing
- Unique cargo door for military/civil application

Image Credit: Lockheed Martin

TTBW–Transonic Truss-Braced Wing

- Truss-braced, thin, very high aspect ratio wing with folding tips
- Conventional, circular pressurized fuselage
- Conventional T-tail
- Conventional under-wing propulsion system w/hybrid-electric variant

D8–Double Bubble

- Double bubble fuselage with unique Pi-Tail
  - Non-circular, pressurized composite fuselage
- Upper aft fuselage boundary layer ingesting (BLI) propulsion system
- Propulsion noise shielding
- Thin, flexible, high aspect ratio wing

Electrified Aircraft Propulsion

(Turbo Electric, Hybrid Electric, All Electric)

- What is Electrified Aircraft Propulsion?
- Why? – reduced carbon, fuel burn, emissions, noise
- Who is building hybrid electric aircraft?
- How we achieve electrified propulsion?
  - Aircraft concepts
  - Hybrid Gas Electric Subproject (HGEP) developing power technology
  - Key related technologies – turbine power extraction, propulsion airframe integration